Title of the Invention: Method and Apparatus for Sequentially Profiling and Solving Problems in Space Mission Analysis

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RELATED APPLICATIONS

This application claims priority from U.S. provisional patent application no. 60/116,546, filed January 21, 1999.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to orbital planning. More particularly, this invention relates to a system and method for orbital planning that allows iterative calculations of orbital parameters to be accomplished in an automated way with one parameter solution serving as input to the next parameter's calculation.

2. Background Art

In the process of a space mission analysis, the analyst must often perform repetitive calculations. Frequently such calculations require the analyst to set up a problem (or "case"), run the problem, and then review the results. After reviewing the results, the analyst will set up another problem based on those results and run the calculations again. Typically, the problems are addressed and solved in order of increasing complexity.

An example of this process is determining how long to fire a spacecraft's engines, and in what direction, in order to place the spacecraft in a desired orbit. This problem can be broken down into two sub-problems. First, the analysts may wish to determine the appropriate duration of firing to achieve the desired orbit in part. After this problem is

solved, and using its solution, the analyst can solve the combined problem of determining the duration *and* direction of the engine firing.

It has generally been necessary to use computer languages and scripts to carry out the sequential profiling and solving of a complex space mission analysis problem. That process is cumbersome and time consuming and, depending on the programming background of the analyst, may require him or her to learn a new programming or script language. The prior art includes one program that makes use of a graphical user interface (GUI) for the individual profiling of a problem, but each problem in a sequence of problems must be profiled and processed manually.

It would therefore be useful to have the ability to solve profiles for space mission planning in an automated way. Ideally a system that allows a user to establish a series of sub-profiles, solve those sub-profiles and provide the response to the next sub-profile problem would give the analyst the most flexibility in performing mission analysis.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method that provides an analyst with the ability to solve profiles for space mission planning.

It is another object of the present invention to provide a computer system that automatically enables an analyst to solve profiles for space mission planning.

It is still another object of the present invention to provide a computer program product that enables a computer to provide an analyst with the ability to automatically solve profiles for space mission planning.

It is an object of the present invention to provide a method that provides an analyst with the ability to establish a series of sub-profiles, and which solves each of those

sub-profiles and provides that solution as a basis for solving the next sub-profile in sequence.

It is another object of the present invention to provide a computer system that provides an analyst with the ability to establish a series of sub-profiles, and which solves each of those sub-profiles and provides that solution as a basis for solving the next sub-profile in sequence.

It is still another object of the present invention to provide a computer program product that enables a computer to provide an analyst with the ability to establish a series of sub-profiles, and which solves each of those sub-profiles and provides that solution as a basis for solving the next sub-profile in sequence.

Some of the above objects are obtained by a method for profiling and solving space mission problems. The method includes creating a space mission analysis scenario, and setting up a control sequence that simulates a problem to be solved in the space mission. The method further includes selecting control variables to be checked in solving the problem, and identifying parameters to be used in defining a desired results that represents an adequate solution to the problem. Additionally, the method includes establishing profiles for each particular sub-problem of the problem to be solved, and running simulations for each of the established profiles to provide a result representing a solution to the problem to be solved.

Others of the above objects are obtained by a computer system embodied according to the present invention. The computer system is adapted to perform profiling and solving space mission problems for which a space mission analysis scenario has been created. The system includes a processor and a memory that is addressable by the processor. The memory includes software instructions adapted to enable the computer

system to perform a number of steps, including setting up a control sequence that simulates a problem to be solved in the space mission, selecting control variables to be checked in solving the problem, and identifying parameters to be used in defining a desired results that represents an adequate solution to the problem. The software instructions are also adapted to enable the computer system to perform steps of establishing profiles for each particular sub-problem of the problem to be solved, and running simulations for each of the established profiles to provide a result representing a solution to the problem to be solved.

Still others of the above objects are obtained by a computer program product embodied according to the present invention. The computer program product enables a computer to perform profiling and to solve space mission problems for which a space mission analysis scenario has been created. The computer program product includes software instructions for enabling the computer to perform predetermined operations, and a computer readable medium embodying the software instructions. The predetermined operations include the steps of setting up a control sequence that simulates a problem to be solved in the space mission, selecting control variables to be checked in solving the problem, and identifying parameters to be used in defining a desired results that represents an adequate solution to the problem. The predetermined operations also include steps of establishing profiles for each particular sub-problem of the problem to be solved, and running simulations for each of the established profiles to provide a result representing a solution to the problem to be solved.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates an example, according to an embodiment of the present invention, of a GUI panel used for selecting components used in defining desired results (i.e., goals) for a given problem.

Fig. 2 illustrates an example, according to an embodiment of the present invention, of a user specifying desired values for the goal elements of a mission.

Fig. 3 illustrates an example, according to an embodiment of the present invention, of profiles being added and being re-ordered

Fig. 4 illustrates an example, according to an embodiment of the present invention, of the Target Sequence window showing that three profiles have been defined for the space mission scenario.

DETAILED DESCRIPTION OF THE INVENTION

According to one embodiment of the present invention, a software program employs a graphical user interface (GUI) to allow the user to set up a series of sub-problems of any desired level of complexity. The program then implements the series automatically and sequentially, incorporating the solution to one sub-problem into the input to the next.

According to a preferred embodiment of the invention, the process claimed herein is carried out in the context of an existing space mission analysis software program, such as the Astrogator module of the Satellite Tool Kit (STK) program produced by Analytical Graphics, Inc. of Malvern, Pennsylvania. The technical literature for the Satellite Tool Kit program is incorporated herein by reference in its entirety, for all purposes.

Using an intuitive GUI, the invention is embodied to allow the analyst to specify different problems in the form of a set of profiles. Each profile comprises one or more selected target variables and one or more desired results. The user can select any given

profile and have the program solve the associated problem. In addition, the user can specify a series of two or more profiles and have the software process them sequentially, as described above.

For example, using the STK Astrogator module, the analyst first creates a space mission analysis scenario. Within that scenario, the analyst sets up a control sequence that simulates the problems to be solved. The invention then allows the analyst, through a GUI, to select all the possible control variables that will be checked in solving the problems and to define components to be used in defining desired results that represent adequate solutions to the problems.

Once the control variables are selected and the desired results are specified, the analyst proceeds to the profiling of each particular sub-problem. Using a GUI panel specifically designed for this purpose, the analyst creates a profile specifying which of the previously selected controls should be varied, and what results should be achieved. The analyst can then use the invention to specify as many different profiles as needed, each with its own lists of controls and desired results.

The analyst can also flag each profile as active or inactive, directing the software program to run only those that are currently active. Since profiles and sequences thereof can be saved together with the space mission analysis scenario, this is a convenience to the analyst in the event that work must be re-run at a later date.

Once the profiles have been specified, the user can command the software via the GUI to run the profiles. After each profile is run, the invention collects the solution to the profile, and applies it as the initial starting point for the next profile (if appropriate).

The invention also allows the analyst to specify many different sets of profiles for different sub-sequences that make up the overall sequence. The invention further allows

one or more sets of profiles to be automatically run as part of another set of profiles. In other words, in running a given sequence that is being investigated as part of a set of profiles, it may be necessary to run a different set of profiles as part of that sequence. The invention allows this "nesting" of profile sets.

When profiles are nested, the invention also allows the analyst to select a desired result of an inner profile to be used as a control variable in an outer profile. It also allows the solution of an inner profile to be used as a result of an outer profile.

As noted above, the present invention is a series of modules running on a computer system to accomplish the mission analysis described. The present invention is implemented via a general-purpose computer.

Referring to **Fig. 1**, the illustrated GUI panel is used for selecting components used in defining desired results ("goals") for a given problem. The Targeted Goal Setup screen **16** allows a user to establish goals and results for a given profile. A series of available "components" are displayed for the user in an "Available Components" window **10**. This shows a user all of the components that are available for the user to specify, for example Eccentricity, Latitude, Altitude and all other components that a user might wish to vary in performing mission planning and analysis. Placement buttons **18** allow the user to select the components that the user wishes to vary.

When the user selects a component, it is transferred to a "Selected Components" window **12**. Here the user can highlight the selected components for subsequent manipulation or specification. Alternatively, the user can de-select a component using the placement buttons **18**.

When a user highlights a component in the component "Selected Components" window **12**, the details and values associated with the selected component are displayed in a "Component Details" window **14** where they can be specified or modified.

Referring to **Fig. 2**, the screen for allowing a user to specify desired values for the goal elements and to determine which are to be used in a given profile is shown. Variables **20** are displayed for the user, as are goals **22** which can be specified by the user for various selected components. Goal elements **24, 26, 28** used in the given profile are marked with an 'x'. Note that in this example, a value is defined for the element of eccentricity, but that element is not used in the profile.

Referring to **Fig. 3**, the screen to add or modify profiles is illustrated. Profiles are added and can be re-ordered if desired in the Add/Modify screen **30** using the GUI of the present invention. Active profiles are marked with an 'x' **32, 34**. In this example, the profile named "Phase-2" is not being run, whereas "Phase-l" and "Phase-3" are being run. This screen also allows a user to edit the profile being run in an Edit screen **36** which allows the user to select the profile to be edited **38**.

Referring to **Fig. 4**, the Target Sequence window **42** is illustrated. The information in this window shows that three profiles **40** have been defined for this space mission scenario.

The system and method of the present invention operates using a number of standard processors known in the art. UNIX processors such as the Silicon Graphics SGI IMPACT™ and SGI 02™, each with the Reality Engine™ or the Infinite Reality™ engine; the IBM RS6000 with Evans & Sutherland Freedom graphics accelerator; the Hewlett-Packard™ HP9000™ with Evans & Sutherland graphics accelerator; the Sun Microsystems SPARC™ station with Evans & Sutherland Freedom graphics accelerator;

the Sun Microsystems UltraSUN™ with Creator3D graphics hardware; Digital Equipment Corporation 4D50T and 4D60T processors, may each be used to implement the present invention. Microsoft Windows operating system hardware also can be used to implement the present invention with MS Windows, Windows95, and Windows NT operating systems with or without OpenGL Accelerators. Generally, all of the above systems should also have 48 Mbytes of memory and at least 75 Mbytes of hard drive space available.

A system and method for sequentially profiling and solving problems in space mission analysis has been disclosed. It will be appreciated by those skilled in the art that other variations may be possible without departing from the scope of the invention as disclosed.